

Spin observables for pion production from pd collisions

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We have calculated the proton analyzing power A_{y0} of the pion-production reaction from pd collisions for one energy close to threshold and for another in the region of the Δ -resonance. A fair reproduction of the experimental data could be obtained in both cases with a model which includes isoscalar and isovector πN rescatterings in s waves, as well as the p -wave rescattering mechanisms mediated by the πNN and $\pi N\Delta$ vertices. For the analyzing power at threshold we found that the initial-state interaction (ISI) is also quite important.

1. INTRODUCTION

Pion-production reactions have the potential to probe the nuclear phenomena at short distance since they typically involve processes transferring large momenta to the target nucleus. On the other hand, the pion is also the principal mediator of the nuclear force, hence, meson production (or absorption) plays a fundamental role in hadron dynamics and the study of these processes may reveal aspects of the meson-baryon coupling, and more generally of meson-exchange phenomena, which would remain otherwise hidden.

Reliable calculations on meson dynamics in few-nucleon systems are extremely difficult, and usually one has to assume that various reaction mechanisms compete in dominating the process. The description of the process is complicated because the treatment of the reaction mechanisms reveals the occurrence of many terms, and this forces one to make further assumptions in order to reduce the number of terms to a few, tractable ones. This reduction clearly introduces ambiguities making it more difficult to extract information about the nuclear wave function at short distances, or about the modifications of the hadron interactions because of the presence of other nucleons. A somewhat simplified situation is found when considering nucleon-induced production close to the pion threshold, since there the s -wave mechanisms of the elementary $NN \rightarrow \pi NN$ inelasticities dominate, while the p -wave mechanisms (including the isobar degrees of freedom) can be treated as corrections.

2. THEORETICAL MODEL

In a recent paper [1], the π -production reaction from pd collisions has been calculated in the threshold region. The model includes meson-exchange rescattering diagrams in s waves, with πN contributions in the isovector and the isoscalar channels. The isovector contribution was generated by a ρ -mediated diagram, and the isoscalar interaction by means of a subtracted σ -exchange model which is suppressed on-shell but enhanced when the rescattered pion is off-mass shell [2]. This off-shell enhancement has been previously advocated [3] to describe the production cross section at threshold for the simpler reaction $pp \rightarrow pp\pi^0$ and represents an alternative explanation for this process with respect to the one given by Lee and Riska [4] in terms of heavy-meson exchange (HME) effects. With the same parameterization suggested by Hamilton we found in Ref. [1] that the pion-production cross section at threshold can be reproduced, while without these off-shell effects the results are underestimated by one order of magnitude.

According to a previous treatment [5] centered around the Δ -resonance region, the effects of the πN p -wave interaction have also been included, via the nonrelativistic πNN vertex, as well as by means of the $\pi N\Delta$ interaction. The intermediate Δ propagation terminates through a ΔN transition determined by the π plus ρ exchange diagrams, where the pseudoscalar meson provides the typical longitudinal structure to the transition potential, while the vector meson generates the transverse contribution.

3. RESULTS

With the same model of Ref. [1], we have calculated the spin observables at threshold. The formalism for the spin observables for this reaction has been given in Ref. [6]. For the $3N$ bound-state in the outgoing channel, we have used the wave functions which have been calculated in Ref. [7]. As two-nucleon input for the three-nucleon equations we have used high rank separable representations [8] of the Paris and the Bonn B potentials, known as PEST and BBEST, respectively. These representations were originally constructed by the Graz group [9]. The three-nucleon dynamics in the initial state (ISI) has been calculated by solving the Faddeev-type Alt-Grassberger-Sandhas equations [10]. More details can be found in Refs. [1,5].

As an example, the angular distribution for the proton analyzing power A_{y0} is shown for the pion center-of-mass momentum $P_{c.m.} \simeq 0.25 m_\pi$, close to the π -production threshold (Fig. 1), and also at higher energy ($P_{c.m.} \simeq 1.36 m_\pi$), close to the Δ resonance (Fig. 2). The two lines shown in Fig. 1 include all production mechanisms we have discussed, and differ because the solid line includes also the effects of ISI, while the dotted line refers to a plane-wave calculation. The ISI effects turn out to be quite important, while at higher energy their effects are smaller. In Fig. 2 we show the modifications obtained when adding the two s -wave diagrams (“ ρ ” and “ σ ”) on top of the p -wave mechanisms, at the Δ resonance. Both these two diagrams are needed for the reproduction of A_{y0} in the forward hemisphere, while at backward angles the situation is still controversial.

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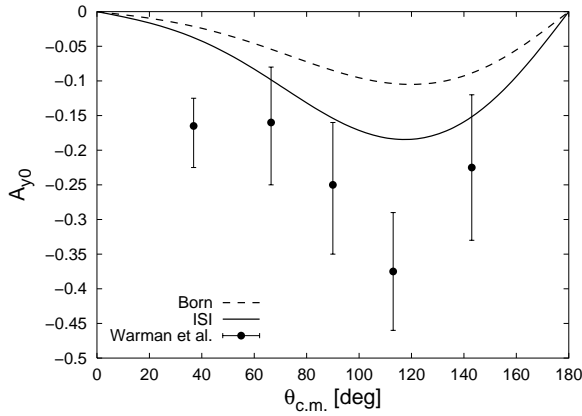


Figure 1. Proton analyzing power A_{y0} for the $\vec{p}d \rightarrow \pi^0 {}^3\text{He}$ process close to threshold. Both calculations include all discussed mechanisms, and the solid line includes also the effect of $3N$ initial-state interaction, while the dashed line is the result obtained in Born approximation. The data are from Ref. [11].

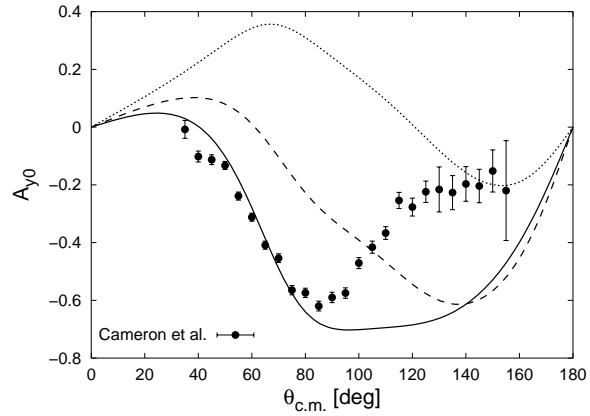


Figure 2. A_{y0} for energies around the Δ resonance. The solid line includes isoscalar off-shell effects, isovector ρ exchanges, Δ rescatterings, and the πNN vertex. The results when excluding the isoscalar off-shell effects are given by the dashed line. The dotted line contains only the p -wave mechanisms. The data are from Ref. [12].

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